Supplement of Biogeosciences, 11, 4443–4457, 2014
http://www.biogeosciences.net/11/4443/2014/
doi:10.5194/bg-11-4443-2014-supplement

Biogeosciences
Open Access

Supplement of

Assessment on the rates and potentials of soil organic carbon sequestration in agricultural lands in Japan using a process-based model and spatially explicit land-use change inventories – Part 2: Future potentials

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Supplementary Material A. Method to create spatially-explicit future land-use map in year 2020.

Grid system

The grid system created in this study has geographical dimensions and coordinate system identical to those in Standard Grid Cell (SGC) system created by former Management and Coordination Agency, the Government of Japan, which has been employed in national statistical surveys in Japan. SGC has four class of layers differs in cell size and its fourth class has same spatial resolution as our grid system created for this study, with spatial resolution of 1/1200 and 1/800 degree (3.0 and 4.5 second), along latitudinal and longitudinal lines, respectively. Size of individual cell of the grid equivalents to a parcel of a square land ca. 100 m on a side, with an area of ca. 10,000 m^2 (1 hectare).

Geographical data sources and interpretation of land-use/land-cover in historical period during year 1970-2006

Brief description on each geographical data sources (with their abbreviated titles in bold) are listed below;

1) **LU**: Land Use Fragmented Mesh Version 1.1 in National Land Numerical Information, created by Ministry of Land, Infrastructure, Transport and Tourism, the Government of Japan. Spatial resolution of 100 x 100 m, along latitudinal and longitudinal lines, respectively. LU map products have been synthesized from various data sources, such as topographical maps, current land usage status maps, satellite images (Landsat, Terra-Aster, ALOS etc.), in combination with several data tables on land-use statistics. Created for fiscal year (FY) 1976, 1987, 1991, 1997, and 2006. From 11 to 16 land-use classifications (paddy field, upland field, orchard, forest, waste area, building use, trunk transportation land, lake, river, etc.) were employed, with the number of classifications differing among some groups of survey periods.

2) **VG**: Vegetation map from Vegetation Naturalness Survey conducted in National Survey on the Natural Environment, created by Ministry of Environment (MOE), the Government of Japan, under authority of Article 4 of the Nature Conservation Law. The VG is a collection set of vector maps with approximately 270 legends of plant communities. Map products created in FY 1983-1986, FY 1989-1993, and FY 1994-1998, compiled in the 3rd, 4th, and 5th survey, respectively, were selected and used in this study. A new nation-wide legend, produced in the 6th survey to unify and arrange locally legends used in predecessor maps, was employed in this study and applied to all predecessor maps by using a legend conversion table provided by MOE.

3) **AL**: Agricultural land map from Basic Survey on Improvement of Agricultural Production Base, created by Ministry of Agriculture, Forestry, and Fisheries (MAFF), the Government of Japan. Vector maps of agricultural fields classified into 4 land-use types (paddy field, upland field, orchard, and grassland). Created in 1992 and 2001. In synthesis of this map product, in some cases, polygons of these types of agricultural fields had been modified so that sum of the area of polygons in each land-use category to be consistent with the agricultural statistics at prefectural level, and thus, may include some bias.

A decision tree was created to decide land-use of each grid cell using legends in LU, VG, and AL as input parameters, to enable compilation of different datasets having different type of information on land-use, legends, and time period. The decision tree was built using structured query language (SQL) and implemented as a PostgreSQL function. The LU, VG, and AL, in overlapping, nearby, or different periods were selected and compiled together to make 6 different groups tagged with different time period, and were applied as input data for the decision tree as summarized in Table A1. As result, grid cells were classified into 9 land-use types; 01 paddy field (PD), 02 upland field (UP), 03 orchards (OC), 04 managed grassland (MG), 05 unmanaged grassland (UG), 06 forest lands (FL), 07 wetlands (WL), 08 settlements (ST), and 09 other lands (OL).

As any of these three geographical data sources alone could not fulfil requirement for our nation-wide simulation due to insufficient classification, accuracy, or time interval, we employed strategy to compile these different geographical data sources to set off merits against the deficit, and to interpret it; e.g. LU had more time series data than other data sources, however, in FY 1991-2006, its classification on agricultural land had only two legend items, 'paddy field' and 'other agricultural fields'. VG had more detail classifications but had only three time series data. Thus LU in FY 1991-2006 was superimposed with VG to enable subdivision of the legend item 'other agricultural fields' in LU into 'paddy field', 'upland field', 'orchards', and 'grasslands'.

Formulation of the decision tree was rather arbitrary and, thus, preliminary. A preliminary validation on the land-use maps using geographical reference dataset on agricultural land management collected in the Basic Soil Environment Monitoring Project, Stationary Monitoring conducted in year 1979-1998 showed that accuracy rate of the land-use map for paddy field, upland field, orchards, and managed grassland were 89, 76, 75, and 71 %, respectively, on average through four waves of the monitoring survey.

Table A1 Dataset used to composite land-use map.

Dataset	Period	land-use map				
		1976	1987	1991	1997	2006
Land use fragmented mesh data, Version 1.1 (LU) [1]	FY 1976	●				
	FY 1987		●			
	FY 1991			●		
	FY 1997				●	
	FY 2006					●
Vegetation map (VG) [2]	FY 1983-1986	●	●			
	FY 1989-1993			●		
	FY 1994-1998				●	●
Agricultural land map (AL) [3]	FY 2001					●

1) National Land Numerical Information (Land Use Fragmented Mesh), Ministry of Land, Infrastructure, Transport and Tourism (MLIT), Japan. http://nlftp.mlit.go.jp/ksj-e/jpgis/datalist/KsjTmplt-L03-b.html

2) Vegetation map, Vegetation Naturalness Survey, National Survey on the Natural Environment, Ministry of Environment, Japan.

3) Agricultural land map, Basic Survey on Improvement of Agricultural Production Base, Ministry of Agriculture, Forestry, and Fisheries, Japan.

Table A2 Spatial-temporal inventory data employed in simulation.

Data type	Spatial resolution	Begin	End	Description
		1970	2008	estimate based on national statistics and survey on agriculture
agricultural activity	prefectural	2009	2020	business as usual scenario or linear change toward future target in 2020[1]
		2021	2100	identical to conditions in 2020 (no temporal change)
		1970	1978	10 years mean values from observation between 1979 and 1988
climate	latitude: 1/120 ° longitude: 1/80 ° (ca. 1 x 1 km)	1979	2009	Observation
		2010	2100	future projection of GCM and CO_2 emission scenarios
		1970	1976	identical to land-use map 1976 (no temporal change)
		1976	1987	interpolation of land-use map 1976 and 1987
		1987	1991	interpolation of land-use map 1987and 1991
land-use	latitude: 1/1200 ° longitude: 1/800 ° (ca. 0.1 x 0.1 km)	1991	1997	interpolation of land-use map 1991 and 1997
		1997	2006	interpolation of land-use map 1997 and 2006
		2006	2020	interpolation of land-use map 2006 and that projected for 2020
		2021	2100	identical to land-use map projected for 2020 (no temporal change)

Future land-use/land-cover data creation

Further, we created future land-use map to be consistent with figures on agricultural land area presented in future agricultural activity scenario created by Agricultural Production Bureau (APB), MAFF. Future scenarios on agricultural activity in accordance with figures presented in the Basic Plan for Food, Agriculture and Rural Areas planned by MAFF with targets set for year 2020 (MAFF-BP) had been created by APB together with business-as-usual scenario (BAU) as baseline scenario (hereafter referred as 'APB scenarios' collectively).

A set of PL/pgSQL functions, a simple land-use change map creation tool (LUC-pg, tentatively named), was developed to enable creation of spatially explicit future land-use map using A) current (latest) land-use map, and B) a land-use change matrix (LUC-matrix), which contains figures on areas of planned or predicted land-use changes to occur, specifying land-use types before and after the occurrence of land-use change, as employed in Approach 2 in GPG-LULUCF for identification of land-use change. The LUC-pg can use LUC-matrix of any arbitrary geographical entity, such as city, prefecture, or country. The LUC-pg does 1) grouping grid cells based on any arbitrary feature or combination of features (e.g. land-use and agricultural commune), 2) tag those grouped grid cells with the order of priority in land-use conversion to occur determined by any arbitrary properties or geographical functions (e.g. land prices, distance to rail station, function of these two parameters, etc.), and 3) proceed conversion of land-use of the grouped grid cells on sorted table according to the order of priority, which continues until it will reach the target levels of total area of land-use change prescribed in the future plan or scenario.

Future land-use map for year 2020 were created by applying LUC-pg to land-use map in year 2006 with APB scenarios. As parameter settings for LUC-pg application, the grid cells were grouped by combination of land-use type and agricultural commune, and the order of priority in land-use conversion was determined by order of total area of the grouped grid cells within each prefecture.

As only target figures on total areas of paddy fields, upland crop fields, orchards, and managed grasslands at prefectural level in future had been given in APB scenarios, firstly, we created LUC-matrix in accordance with the APB scenarios with some arbitrary assumptions in land-use change patterns (i.e. converted from/to). One major assumption was made with regard to conversion of agricultural lands (paddy fields, upland crop fields, orchards, and managed grasslands) to non-agricultural lands, with assuming two different contrasting and rather exaggerated cases on the 'converted to' land-use types;

Urbanization (URB): Lands converted from agricultural lands will be converted to settlements (no organic matter input to soil, no vegetation cover).

Abandonment (ABN): Land converted from agricultural lands will be converted to unmanaged grasslands (organic matter supplied at a fixed rate, covered by vegetation).

As a result, two different future maps were created for each of the two APB scenarios in correspondent with these different two assumptions.

For a group of a set of six of the land-use maps from 1976 to 2006 and a map of future scenario 2020, for each grid cells or a group of grid cells, a year of land-use conversion were generated between years of two consecutive land-use maps using random number generation function of PostgreSQL. This operation could provide an interpolation of changes in total area of each land-use types at prefectural level during intermittent years between two consecutive but discontinuous maps.

It should be noted that, prior to the generation of land-use conversion years, each of the six land-use maps was modified by applying LUC-pg with arbitrary formulated LUC-matrix so that total area of paddy field, upland field, orchards, and managed grassland to be in a good agreement with corresponding figures in national agricultural statistics in corresponding year.

Necessity or significance on the application of LUC-pg for existing land-use map for past and current, in view of production for more appropriate land-use change data for LULUCF accounting, were questionable as it would cause decline of map quality. Such operation should be performed only when figures in LUC-matrix were confirmed to have greater accuracy and credibility than geographical map.

Transformation of geodetic reference system, rasterization of the vector map, were performed using GDAL, OGR, GRASS GIS, Quantum GIS (QGIS), and tools provided by The Open Source Geo-spatial Foundation (OSGeo). Computational operations to compile LU, VG, and AL dataset and to superimpose them on the grid system were performed using PostGIS on PostgreSQL database.

Land-use change matrix (LUC matrix) used for future land-use scenarios from year 2006 to 2020.

Table A3 Land-use change matrix for different future land-use scenarios from year 2006 to 2020 (unit: 10^3 ha); 01 PD: paddy fields, 02 UP: upland crop fields, 03 OC: orchards, 04 MG: managed grasslands, 05 UG: unmanaged grasslands, 06 FL: forest lands, 07 WL: wetlands, 08 ST: settlements, 09 OL: other lands.

a) BAU & Urbanization scenario

		To									From		
		01 PD	02 CL	03 OC	04 MG	05 UG	06 FL	07 WL	08 ST	09 OL	TOT [1)]	REM [2)]	CON [3)]
From	01 PD	1,635	0	0	0	0	0	0	166	0	1,800	1,635	166
	02 CL	0	1,741	0	0	0	0	0	129	0	1,871	1,741	129
	03 OC	0	0	270	0	0	0	0	58	0	328	270	58
	04 MG	0	0	0	578	0	0	0	51	0	628	578	51
	05 UG	0	0	0	0	2,316	0	0	0	0	2,316	2,316	0
	06 FL	0	0	0	0	0	24,725	0	0	0	24,725	24,725	0
	07 WL	0	0	0	0	0	0	917	0	0	917	917	0
	08 ST	0	0	0	0	0	0	0	2,645	0	2,645	2,645	0
	09 OL	0	0	0	0	0	0	0	0	1,971	1,971	1,971	0
To	TOT [1)]	1,635	1,741	270	578	2,316	24,725	917	3,049	1,971	37,201		
	REM [2)]	1,635	1,741	270	578	2,316	24,725	917	2,645	1,971		36,797	
	CON [3)]	0	0	0	0	0	0	0	404	0			404

1) total, 2) sum of the area for land remaining in the same land-use category, 3) sum of the area for land converted to other land-use types

b) BAU & Abandonment scenario

		To									From		
		01 PD	02 CL	03 OC	04 MG	05 UG	06 FL	07 WL	08 ST	09 OL	TOT	REM	CON
From	01 PD	1,635	0	0	0	166	0	0	0	0	1,800	1,635	166
	02 CL	0	1,741	0	0	129	0	0	0	0	1,871	1,741	129
	03 OC	0	0	270	0	58	0	0	0	0	328	270	58
	04 MG	0	0	0	578	51	0	0	0	0	628	578	51
	05 UG	0	0	0	0	2,316	0	0	0	0	2,316	2,316	0
	06 FL	0	0	0	0	0	24,725	0	0	0	24,725	24,725	0
	07 WL	0	0	0	0	0	0	917	0	0	917	917	0
	08 ST	0	0	0	0	0	0	0	2,645	0	2,645	2,645	0
	09 OL	0	0	0	0	0	0	0	0	1,971	1,971	1,971	0
To	TOT	1,635	1,741	270	578	2,720	24,725	917	2,645	1,971	37,201		
	REM	1,635	1,741	270	578	2,316	24,725	917	2,645	1,971		36,797	
	CON	0	0	0	0	404	0	0	0	0			404

1) total, 2) sum of the area for land remaining in the same land-use category, 3) sum of the area for land converted to other land-use types

c) MAFF-BP & Urbanization scenario

		To									From		
		01 PD	02 CL	03 OC	04 MG	05 UG	06 FL	07 WL	08 ST	09 OL	TOT	REM	CON
From	01 PD	1,800	0	0	0	0	0	0	0	0	1,800	1,800	0
	02 CL	60	1,756	0	55	0	0	0	0	0	1,871	1,756	115
	03 OC	0	0	306	4	0	0	0	18	0	328	306	22
	04 MG	0	0	0	628	0	0	0	0	0	628	628	0
	05 UG	0	0	0	0	2,316	0	0	0	0	2,316	2,316	0
	06 FL	0	0	0	0	0	24,725	0	0	0	24,725	24,725	0
	07 WL	0	0	0	0	0	0	917	0	0	917	917	0
	08 ST	0	0	0	0	0	0	0	2,645	0	2,645	2,645	0
	09 OL	0	0	0	0	0	0	0	0	1,971	1,971	1,971	0
To	TOT	1,860	1,756	306	687	2,316	24,725	917	2,663	1,971	37,201		
	REM	1,800	1,756	306	628	2,316	24,725	917	2,645	1,971		37,064	
	CON	60	0	0	59	0	0	0	18	0			137

1) total, 2) sum of the area for land remaining in the same land-use category, 3) sum of the area for land converted to other land-use types

d) MAFF-BP & Abandonment scenario

		To									From		
		01 PD	02 CL	03 OC	04 MG	05 UG	06 FL	07 WL	08 ST	09 OL	TOT	REM	CON
From	01 PD	1,800	0	0	0	0	0	0	0	0	1,800	1,800	0
	02 CL	60	1,756	0	55	0	0	0	0	0	1,871	1,756	115
	03 OC	0	0	306	4	18	0	0	0	0	328	306	22
	04 MG	0	0	0	628	0	0	0	0	0	628	628	0
	05 UG	0	0	0	0	2,316	0	0	0	0	2,316	2,316	0
	06 FL	0	0	0	0	0	24,725	0	0	0	24,725	24,725	0
	07 WL	0	0	0	0	0	0	917	0	0	917	917	0
	08 ST	0	0	0	0	0	0	0	2,645	0	2,645	2,645	0
	09 OL	0	0	0	0	0	0	0	0	1,971	1,971	1,971	0
To	TOT	1,860	1,756	306	687	2,334	24,725	917	2,645	1,971	37,201		
	REM	1,800	1,756	306	628	2,316	24,725	917	2,645	1,971		37,064	
	CON	60	0	0	59	18	0	0	0	0			137

1) total, 2) sum of the area for land remaining in the same land-use category, 3) sum of the area for land converted to other land-use types

A step-by-step guidance on the method to create spatially-explicit future land-use map with specified future land area target or prediction.

[Step 1] Define Land-use Change Unit (LUC-Unit) by aggregating grid-cells with grouping by prefecture, city, agricultural commune, zoning (e.g. for land-use change regulation) and land-use type. Calculate area of the LUC-Unit. PD: paddy fields, UP: upland crop fields.

Cell ID	Prefecture	City	Agcom [1]	Zone	Soil	Land-use	Cell area	Unit ID	Unit area
1	08	001	101	1	A	PD	1	1	3
2	08	001	101	1	A	PD	1	1	3
3	08	001	101	1	A	PD	1	1	3
4	08	001	101	1	B	UP	1	2	2
5	08	001	101	1	B	UP	1	2	2
6	08	001	102	1	B	UP	1	3	1
7	08	001	102	1	B	PD	1	4	2
8	08	001	102	1	B	PD	1	4	2
9	08	001	102	1	C	PD	1	5	1
10	08	001	103	1	C	PD	1	6	1
...	...	...	...	...	...	...	...	...	...

[Step 2] Assign Land-use Change Likeliness Index (LUC-LI), either as numeric or integer data type indicating relative likeliness for land-use conversion to occur, according to user-specified model of land-use change trend, land-use planning, and policy implementation. The LUC-LI can be set by many different ways with different objectives. By adding various geographical information as additional attributes of grid cells, e.g. distance from train station, land price, population in city or smaller size local community, and soil types, etc., may help to build more sophisticated and complex model to predict land-use change that takes account multiple geographical attributes data as input parameters. PD: paddy fields, UP: upland crop fields.

Cell ID	Prefecture	City	Agcom [1]	Zone	Soil	Land-use	Cell area	Unit ID	Unit area	LUC-LI
1	08	001	101	1	A	PD	1	1	3	
2	08	001	101	1	A	PD	1	1	3	
3	08	001	101	1	A	PD	1	1	3	
4	08	001	101	1	B	UP	1	2	2	
5	08	001	101	1	B	UP	1	2	2	
6	08	001	102	1	B	UP	1	3	1	
7	08	001	102	1	B	PD	1	4	2	
8	08	001	102	1	B	PD	1	4	2	

9	08	001	102	1	C	PD	1	5	1	
10	08	001	103	1	C	PD	1	6	1	
...	...	...	...	...	...	...	...	...	...	...

[Step 3] Define range of grid-cells for which land-use change to occur by the following steps;

Step 3.1 - Select a land-use type listed in land-use change matrix (e.g. Paddy fields (PD)) prepared for a geographical entity (e.g. a zone in a prefecture) and obtain a set of land-use change patterns with specified area of land-use conversions for each. Probability of land-use change (%) is calculated according to relative proportion of the specified area of land-use conversion among all other land-use change patterns, as indicated below in table. In this example, a total 4,000 ha (1,000 + 3,000) of Paddy fields should be converted to other land-use types, with probability to be converted to Upland crop fields and Settlements equal to 25 and 75 %, respectively.

		Unit	To 01 PD	 02 UP	 03 OC	 04 MG	 05 UG	 06 FL	 07 WL	 08 ST	 09 OL
From	01 PD	ha	16,000	1,000	0	0	0	0	0	3,000	0
		%	-	25	0	0	0	0	0	75	0

01 PD: paddy fields, 02 UP: upland crop fields, 03 OC: orchards, 04 MG: managed grasslands, 05 UG: unmanaged grasslands, 06 FL: forest lands, 07 WL: wetlands, 08 ST: settlements, 09 OL: other lands.

Step 3.2 - For grid-cells in a geographical entity specified in the land-use change matrix (e.g. a zone in a prefecture), having a land-use type selected in Step 3.1 (e.g, Paddy fields), sort them and calculate cumulative sum of the area of LUC-Unit according to the order of LUC-LI assigned in Step 2. PD: paddy fields.

Cell ID	Prefecture	City	Agcom [1]	Zone	Soil	Land-use	Cell area	Unit ID	Unit area	LUC-LI	Unit area cum. Sum
50	08	001	301	1	C	PD	1	15	3	**1**	**3**
51	08	001	301	1	C	PD	1	15	3	**1**	**3**
52	08	001	301	1	C	PD	1	15	3	**1**	**3**
304	08	066	210	1	A	PD	1	87	3	**2**	**6**
305	08	066	210	1	A	PD	1	87	3	**2**	**6**
306	08	066	210	1	A	PD	1	87	3	**2**	**6**
9	08	001	102	1	C	PD	1	5	1	**3**	**7**
126	08	025	003	1	B	PD	1	213	2	**4**	**9**
127	08	025	003	1	B	PD	1	213	2	**4**	**9**
...	...	...	...	...	...	...	...	...	...	...	...
6	08	001	102	1	B	PD	1	3	1	**598**	**4000**
512	08	077	005	1	D	PD	1	462	2	**623**	**4002**
513	08	077	005	1	D	PD	1	462	2	**623**	**4002**
...	...	...	...	...	...	...	...	...	...	...	...

Step 3.3 - For grid-cells showing values of the cumulative sum of the LUC-Unit less than the area of land-use conversion for target land-use type as specified in the Step 3.1 (e.g. 4,000 ha of Paddy fields should be converted), assign new land-use type (e.g. Settlements) based on the probability of land-use change specified for each land-use change patterns defined in the Step 3.1 with random number generation for uniform distribution of integer ranging from 0 to 100. In this example, a grid-cell with the assigned random number ranging from 0 to 24 will be assigned a new land-use type 'upland crop fields (UP)', while those with the random number ranging from 25 to 100 will be assigned 'settlements (ST)'.

Cell ID	Prefecture	City	Agcom [1]	Zone	Soil	Land-use	Cell area	Unit ID	Unit area	LUC-LI	Unit area cum. sum	Random number	New land-use
50	08	001	301	1	C	PD	1	15	3	1	3	**34**	**ST**
51	08	001	301	1	C	PD	1	15	3	1	3	**12**	**UP**
52	08	001	301	1	C	PD	1	15	3	1	3	**38**	**ST**
304	08	066	210	1	A	PD	1	87	3	2	6	**38**	**ST**
305	08	066	210	1	A	PD	1	87	3	2	6	**91**	**ST**
306	08	066	210	1	A	PD	1	87	3	2	6	**39**	**ST**
9	08	001	102	1	C	PD	1	5	1	3	7	**26**	**ST**
126	08	025	003	1	B	PD	1	213	2	4	9	**90**	**ST**
127	08	025	003	1	B	PD	1	213	2	4	9	**24**	**UP**
...	...	...	...	...	...	...	...	...	...	...	...	...	...
6	08	001	102	1	B	PD	1	3	1	598	4000	**90**	**ST**
512	08	077	005	1	D	PD	1	462	2	623	4002	-	**PD**
513	08	077	005	1	D	PD	1	462	2	623	4002	-	**PD**
...	...	...	...	...	...	...	...	...	...	...	...	...	...

Supplementary Material B. Key quantities on agricultural activity estimated for year 1970-2008 and those in future scenarios BAU and MAFF-BP projected toward year 2020

Table B1. Area of each land-use (employed in simulation), unit: 10^3 ha.

Land-use [1)]		1970	1980	1990	2000	2008	LUC [2)]	BAU 2020		MAFF-BP 2020	
01	PD	2,866	2,586	2,139	1,875	1,642		1,512	(92)	1,739	(106)
02	UP	1,453	1,621	1,845	1,806	1,809		1,695	(94)	1,712	(95)
03	OC	611	570	454	347	304		255	(84)	292	(96)
04	MG	505	560	647	630	580		538	(93)	653	(113)
sub-total		*5,435*	*5,337*	*5,085*	*4,657*	*4,335*		*3,999*	*(92)*	*4,395*	*(101)*
05	UG	956	1,024	1,235	1,500	1,537	URB	1,537	(100)	1,537	(100)
							ABN	1,953	(127)	1,557	(101)
06	FL	442	434	393	296	357		357	(100)	357	(100)
07	WL	48	46	38	38	38		38	(100)	38	(100)
08	ST	64	89	153	351	519	URB	854	(165)	458	(88)
							ABN	439	(85)	439	(85)
09	OL	85	100	126	188	245		245	(100)	245	(100)
Total		*7,030*	*7,030*	*7,030*	*7,030*	*7,030*	*URB*	*7,030*	*(100)*	*7,030*	*(100)*
							ABN	*7,030*	*(100)*	*7,030*	*(100)*

1) PD: paddy; UP: upland fields; OC: orchards; MG: managed grasslands; UG: unmanaged grasslands; FL: forest lands.
2) LUC: land-use change scenario. Same area was applied for both URB and ABN land-use change scenarios for PD, UP, OC, MG, FL, WL, and OL.

Table B2. Amount of plant residue input to fields (employed in simulation), unit: Gg C yr^{-1}.

Land-use [1)]		1970	1980	1990	2000	2008	LUC [2)]	BAU 2020		MAFF-BP 2020	
01	PD	4,204	3,460	3,923	4,338	3,947		3,410	(86)	4,300	(109)
02	UP	992	1,205	1,425	1,397	1,303		1,173	(90)	1,793	(138)
03	OC	341	331	294	275	252		208	(83)	246	(98)
04	MG	1,231	1,367	1,655	1,592	1,429		1,328	(93)	1,358	(95)
05	UG	3,634	3,891	4,695	5,700	5,841	URB	5,841	(100)	5,841	(100)
							ABN	7,421	(127)	5,916	(101)
06	FL	884	868	787	593	714		714	(100)	714	(100)
Total		*11,286*	*11,122*	*12,779*	*13,895*	*13,486*	*URB*	*12,674*	*(94)*	*14,252*	*(106)*
							ABN	*14,254*	*(106)*	*14,327*	*(106)*

2) LUC: land-use change scenario.

Table B3. Number of livestocks, unit: 10^3 heads.

Livestock		1970	1980	1990	2000	2008	BAU 2020		MAFF-BP 2020	
Dairy cow	milking	888	1,069	1,080	992	862	743	(86)	668	(77)
	heifer, dry	314	355	346	259	213	184	(86)	140	(66)
	U2Y [1)]	608	646	605	513	458	395	(86)	396	(86)
Beef cattle	2YO [1)]	831	723	854	870	994	1,162	(117)	1,272	(128)
	U2Y [1)]	984	743	826	826	829	969	(117)	881	(106)
	dairy breed	186	716	1,039	1,123	1,067	830	(78)	814	(76)
Pigs	fattening	5,667	8,609	10,634	8,807	8,777	8,278	(94)	8,914	(102)
	breeding	844	1,169	1,182	1,000	967	912	(94)	948	(98)
Poultry	hen, 6MO [1)]	43	34	40	38	39	41	(105)	39	(100)
	hen, U6M [1)]	120	124	138	141	143	130	(91)	136	(95)
	broiler	55	128	151	108	103	106	(103)	106	(103)

Numbers in parenthesis presented for 2020 scenarios indicate percentage values compared with those in 2008.
1) 2YO: 2 years and older; U2Y: under 2 years old; U6M: under 6 months old; 6MO: 6 months and older.
2) Business-As-Usual scenario.
3) Ministry of Agriculture, Forestry, and Fishery (2010), Basic Plan on Food, Agriculture and Rural Areas.

Table B4. Amount of organic carbon in compost, slurry, and excreta from different sources (original estimate), unit: Gg C yr^{-1}.

							BAU		MAFF-BP	
	Sources	1970	1980	1990	2000	2008	2020		2020	
Compost [2]	LW	1,775	2,259	2,557	2,317	2,247	2,155	(96)	2,135	(95)
	BD	300	483	512	394	233	172	(74)	173	(74)
	SM	2,992	3,353	3,755	3,382	3,211	2,977	(93)	3,006	(94)
	FW	0	1	4	23	58	59	(102)	59	(102)
	ST	1,279	874	890	535	437	405	(93)	399	(91)
	sub-total	*6,346*	*6,970*	*7,718*	*6,651*	*6,186*	*5,768*	*(93)*	*5,772*	*(93)*
Slurry [1,2]	SL_UP	17	18	18	14	12	10	(83)	13	(108)
	SL_MG	11	17	19	20	19	14	(74)	13	(68)
	sub-total	*28*	*35*	*37*	*34*	*31*	*24*	*(77)*	*26*	*(84)*
Excreta [1,2]	EX_MG	15	21	24	25	25	22	(88)	23	(92)
Total		*6,389*	*7,026*	*7,779*	*6,710*	*6,242*	*5,814*	*(93)*	*5,962*	*(96)*

Numbers in parenthesis presented for 2020 scenarios indicate percentage values compared with those in 2008.
LW: livestock waste; BD: bedding for livestock; SM: secondary materials for composting livestock waste; FW: food waste; ST: rice and wheat straw.
SL_UP: slurry applied to upland fields; SL_MG: slurry applied to managed grasslands. EX_MG: excreta applied to managed grasslands.
1) A conversion factor of 0.5 was applied for above listed values of slurry and excreta prior to determination of the annual input of farm-yard manure in RothC to take account relatively fast decomposition of these organic matters compared to composted manure.
2) Values shown in this table were estimated based on agricultural field area data in national statistics and thus were not identical to those listed in Table 5 that used area data from land-use map data applied in simulation.

Table B5. Amount of manure applied to fields (employed in simulation), unit: Gg C yr^{-1}.

						BAU		MAFF-BP	
Land-use [1]	1970	1980	1990	2000	2008	2020		2020	
01 PD	2,191	1,855	1,138	807	692	561	(81)	772	(112)
02 UP	3,457	3,763	3,497	2,782	2,457	1,981	(81)	3,067	(125)
03 OC	577	524	381	398	340	247	(73)	325	(96)
04 MG	0	727	2,701	2,510	2,336	2,813	(120)	1,298	(56)
Total	*6,225*	*6,869*	*7,717*	*6,497*	*5,825*	*5,602*	*(96)*	*5,462*	*(94)*

Same amount of manure was applied for both s1 and s2 land-use change scenarios in each land-use type.
1) PD: paddy; UP: upland fields; OC: orchards; MG: managed grasslands.

Table B6. Amount of slurry applied to fields (employed in simulation), unit: Gg C yr^{-1}.

						BAU		MAFF-BP	
Land-use [1]	1970	1980	1990	2000	2008	2020		2020	
02 UP	27	34	36	27	23	25	(109)	24	(104)
04 MG	37	33	39	39	35	25	(71)	25	(71)
Total	*64*	*67*	*75*	*66*	*58*	*50*	*(86)*	*49*	*(84)*

Same amount of slurry was applied for both URB and ABN land-use change scenarios in each land-use type.
1) CL: croplands; MG: managed grasslands.

Table B7. Amount of excreta input to field (employed in simulation), unit: Gg C yr^{-1}.

						BAU		MAFF-BP	
Land-use [1]	1970	1980	1990	2000	2008	2020		2020	
04 MG	54	40	47	49	46	43	(93)	44	(96)

Same amount of excreta was applied for both URB and ABN land-use change scenarios.
1) MG: managed grasslands.

Table B8. Rate of plant residue application to fields, unit: Mg C ha^{-1} yr^{-1}.

						BAU		MAFF-BP	
Land-use [1]	1970	1980	1990	2000	2008	2020		2020	
01 PD	1.5	1.3	1.8	2.3	2.4	2.3	(94)	2.5	(103)
02 UP	0.7	0.7	0.8	0.8	0.7	0.7	(96)	1.1	(146)
03 OC	0.6	0.6	0.7	0.8	0.8	0.8	(99)	0.8	(101)
04 MG	2.4	2.4	2.6	2.5	2.5	2.5	(100)	2.1	(84)

1) PD: paddy; UP: upland fields; OC: orchards; MG: managed grasslands.

Table B9. Rate of manure application to fields, unit: Mg C ha^{-1} yr^{-1}.

Land-use [1]	1970	1980	1990	2000	2008	BAU 2020	MAFF-BP 2020
01 PD	0.8	0.7	0.5	0.4	0.4	0.4 (88)	0.4 (105)
02 UP	2.4	2.3	1.9	1.5	1.4	1.2 (86)	1.8 (132)
03 OC	1.0	0.9	0.8	1.2	1.1	1.0 (87)	1.1 (100)
04 MG	0.0	1.3	4.2	4.0	4.0	5.2 (130)	2.0 (49)

1) PD: paddy; UP: upland fields; OC: orchards; MG: managed grasslands.

Table B10. Rate of overall input of organic carbon (sum of plant residue, manure, slurry, and excreta) to fields, unit: Mg C ha^{-1} yr^{-1}.

Land-use [1]	1970	1980	1990	2000	2008	BAU 2020	MAFF-BP 2020
01 PD	2.2	2.1	2.4	2.7	2.8	2.6 (93)	2.9 (103)
02 UP	3.1	3.1	2.7	2.3	2.1	1.9 (90)	2.9 (137)
03 OC	1.5	1.5	1.5	1.9	2.0	1.8 (92)	2.0 (101)
04 MG	2.5	3.8	6.8	6.6	6.6	7.8 (118)	4.1 (63)

1) PD: paddy; UP: upland fields; OC: orchards; MG: managed grasslands.

Supplementary Material C. Equations used to estimate application rate of organic amendments in agricultural fields

[Plant residues]

Equations set C.1 (plant residue production for major crops and vegetables);

Annual plant residue inputs to soils in different prefecture and year were estimated for each cropping group using the following equations;

Equation C.1.1: for rice, wheat, sweet potato, beans, millet, and vegetables;

$$\mathrm{RSC}_{cg,pr,y} = \begin{cases} \sum_{c=1}^{nc_{cg}} \left(\mathrm{YFW}_{c,pr,y}\right) \cdot \mathrm{YD2F}_{cg} \cdot \mathrm{RS2Y}_{cg} \cdot \mathrm{RSINC}_{cg,rg,y} \cdot \mathrm{RSCC}_{cg} \\ \sum_{c=1}^{nc_{cg}} \left(\mathrm{YFW}_{c,pr,y} \cdot \mathrm{YD2F}_{c} \cdot \mathrm{RS2Y}_{c}\right) \cdot \mathrm{RSINC}_{cg,rg,y} \cdot \mathrm{RSCC}_{cg} \end{cases}$$

Equation C1.2: for orchards, manure crops, and forage;

$$\mathrm{RSC}_{cg,pr,y} = \sum_{c=1}^{nc_{cg}} \left(\mathrm{RSCA}_{c,y} \cdot \mathrm{CA}_{c,pr,y}\right) \cdot \mathrm{RSINC}_{cg,rg,y} \cdot \mathrm{RSCC}_{cg}$$

Equation C1.2.1: orchards;

$$\mathrm{RSCA}_{c,y} = const_c$$

Equation C1.2.2: manure crops;

for crops other than grass,

$$\mathrm{RSCA}_{c,y} = \mathrm{BMCA}_c$$

$$\mathrm{BMCA}_c = \mathrm{YDWCA}_c \cdot (1 + \mathrm{BG2Y}_c)$$

$$\mathrm{YDWCA}_c = constc$$

for Italian ryegrass,

See Equation C1.2.3.

for grass excluding Italian ryegrass (including mixed seeding of *Poaceae* and *Fabaceae*),

See Equation C1.2.4.

Equation C1.2.3: forage of Italian ryegrass;

$$\mathrm{RSCA}_{\mathrm{GRIR},y} = \mathrm{RSBGCA}_{\mathrm{GRIR},y}$$

$$\mathrm{RSBGCA}_{\mathrm{GRIR},y} = \mathrm{RSBGCA}_{\mathrm{GRP},1982-84} \cdot \frac{\mathrm{YFW}_{\mathrm{GR},y}}{\mathrm{YFW}_{\mathrm{GR},1983}}$$

Equation C1.2.4: forage of grass excluding Italian ryegrass (including mixed seeding of *Poaceae* and *Fabaceae*);

$$\mathrm{RSCA}_{\mathrm{GRNI},y} = \left(\mathrm{RSBGCA}_{\mathrm{GR},y} + \mathrm{RSUGCA}_{\mathrm{GR},y}\right) + \frac{\mathrm{BMCA}_{\mathrm{GR},y}}{\mathrm{YRRE}}$$

$$\mathrm{RSBGCA}_{\mathrm{GR},y} = \mathrm{RSBGCA}_{\mathrm{GRP,1982-84}} \cdot \frac{\mathrm{YFWCA}_{\mathrm{GR,1997-2005}}}{\mathrm{YFWCA}_{\mathrm{GRP,1997-2005}}} \cdot \frac{\mathrm{YFWCA}_{\mathrm{GR},y}}{\mathrm{YFWCA}_{\mathrm{GR,1996}}}$$

$$\mathrm{RSUGCA}_{\mathrm{GR},y} = \mathrm{RSUGCA}_{\mathrm{GRP,1982-84}} \cdot \frac{\mathrm{YFWCA}_{\mathrm{GR,1997-2005}}}{\mathrm{YFWCA}_{\mathrm{GRP,1997-2005}}} \cdot \frac{\mathrm{YFWCA}_{\mathrm{GR},y}}{\mathrm{YFWCA}_{\mathrm{GR,1996}}}$$

$$\mathrm{YFWCA}_{\mathrm{GR,1997-2005}} = \sum_{\mathrm{y}=1997}^{2005} \left(\frac{\mathrm{YFWCA}_{\mathrm{GRP,y}} \cdot \mathrm{CA}_{\mathrm{GRP,y}} + \mathrm{YFWCA}_{\mathrm{GRPF,y}} \cdot \mathrm{CA}_{\mathrm{GRPF,y}}}{\mathrm{CA}_{\mathrm{GRP,y}} + \mathrm{CA}_{\mathrm{GRPF,y}}} \right) / 9$$

$$\mathrm{BMCA}_{\mathrm{GR},y} = \mathrm{YDWCA}_{\mathrm{GR,1996}} \cdot (1 + \mathrm{BG2Y}_{\mathrm{GR}}) \cdot \frac{\mathrm{YFWCA}_{\mathrm{GR},y}}{\mathrm{YFWCA}_{\mathrm{GRPF,1996}}}$$

$$\mathrm{YDWCA}_{\mathrm{GR,1996}} = \frac{\mathrm{YDWCA}_{\mathrm{GRPF,1996}} \cdot \mathrm{CA}_{\mathrm{GRPF,1997-2005}} + \mathrm{YDWCA}_{\mathrm{GRP,1996}} \cdot \mathrm{CA}_{\mathrm{GRP,1997-2005}}}{\mathrm{CA}_{\mathrm{GRPF,1997-2005}} + \mathrm{CA}_{\mathrm{GRP,1997-2005}}}$$

where,

RSC = mass of organic carbon in plant residue to be incorporated into soils in a year, Mg C yr^{-1}.

c = cropping type (e.g. tomato, two-row barley, Italian ryegrass, etc.).

cg = cropping group (e.g. paddy rice, wheat, vegetables, forage and manure crop, etc.).

nc = the number of cropping types in a cropping group (paddy rice (3); wheat (4); sweet potato (1); beans (4); millet (1); vegetables (38); forage and manure crop (8); industrial crop (3); fruit and tea (2)).

ncg = the number of cropping groups in a land-use type (paddy fields (3); upland fields (7); orchards (1); managed grasslands (1)).

pr = prefecture.

rg = region (group of prefectures).

y = year.

const = fixed constant taken from literatures.

YFW = yield in fresh weight, Mg yr^{-1}.

YD2F = proportion of dry weight against fresh weight of yield.

RS2Y = proportion of residues by weight against yield, dry weight basis.

RSINC = proportion of plant residues to be returned to soils against other usages or treatments such as bedding for live-stock, handicraft, incineration, and disposal.

RSCC = concentration of organic carbon in plant residue, dry matter basis, g g^{-1}.

CA = cropping area, ha.

RSCA = plant residue production per a unit cropping area in a year, Mg ha^{-1} yr^{-1}.

BMCA = total biomass of grass including above and below ground biomass per unit cropping area, Mg ha^{-1}.

YDWCA = yield per a unit cropping area in a year in dry weigh, Mg ha^{-1} yr^{-1}.

YFWCA = yield per a unit cropping area in a year in dry weigh, Mg ha^{-1} yr^{-1}.

BG2Y = proportion of below ground biomass against yield in dry weight.

RSBGCA = below ground biomass residue input to soils per a unit cropping area in a year, Mg ha^{-1} yr^{-1}.

RSUGCA = upper ground biomass residue input to soils per a unit cropping area in a year, Mg ha^{-1} yr^{-1}.

YRRE = mean of number of years for renewal of grasslands.

GR = grass.

GRIR = Italian ryegrass.

GRNI = grass excluding Italian ryegrass.

GRP = grass of *Poaceae* family, e.g. Italian ryegrass.

GRPF = grass with mixed seeding of *Poaceae* and *Fabaceae* families.

Equation C.1.3 (plant residue input to soil in different land-use types);

$$\mathrm{RSCI}_{lu,pr,y} = \sum_{cg=1}^{ncg_{lu}} \left(\mathrm{RSC}_{cg,pr,y}\right) / \mathrm{A}_{lu,pr,y}$$

where,

RSCI = annual rate of plant residue organic carbon input to soils, Mg C ha^{-1} yr^{-1}.

lu = land-use type, including paddy fields, upland fields, orchards, and managed grasslands.

pr = prefecture.

y = year.

cg = cropping group (e.g. paddy rice, wheat, vegetables, forage and manure crop, etc.).

ncg = the number of cropping groups in a land-use type (paddy fields (3); upland fields (7); orchards (1); managed grasslands (1)).

A = area of field in each land-use type, ha.

Table C1 List of parameters used for estimation for production and application of plant residues.

crop group		YD2F [1)]	RSCA [2)]	RS2Y [3)]	RSINC [4)]	BMCA [5)]	YRRE [6)]	RSCC [7)]
rice (1)	straws			1.20	0.32-0.64-0.95			
	husks	0.85		0.22	0-0.20-0.35			
	roots & stables			0.27	1.0			
wheat (4)	shoots	0.85		0.97	0-0.63-1.0			
	roots & stables			0.42	1.0			
sweet potato (1)		0.30		0.50	0.46			0.4
beans (4)		0.85-0.90		0.9-1.0	0.75			
millet (1)		0.85		1.50	0.46			
vegetables (29)		0.05-0.25		0.2-5.0	0.46			
orchards (18)			1.0-15.4		1.0			
forage & manure crops (9)			3.6-15.9		1.0	5.6-17.2	10	

Two values separated with hyphen indicate minimum and maximum values, whereas three values separated with two hyphens indicate minimum, mean, and maximum values of parameter.

1) YD2F: proportion of dry weight against fresh weight of yield.

2) RSCA: proportion of residues by weight against yield, dry weight basis.
3) RS2Y: proportion of residues by weight against yield, dry weight basis.
4) RSINC: proportion of plant residues to be returned to soils against other usages or treatments such as bedding for live-stock, handicraft, incineration, and disposal.
5) BMCA: total biomass including both above and below ground biomass per unit cropping area, Mg ha^{-1}.
6) YRRE: mean of number of years for renewal of grasslands.
7) RSCC: concentration of organic carbon in plant residue, dry matter basis, g g^{-1}. Parameter value was taken from Shirato et. al. (unpublished).

[Live-stock waste compost]

Equation C.2.1 (Live-stock waste);

$$\mathrm{LWFW}_{ls,pr,y} = \sum_{lss=1}^{nlss_{ls}} \left(\mathrm{LSN}_{lss,pr,y} \cdot \mathrm{LWE}_{lss} \cdot \mathrm{DN}_{y}\right)$$

where,

ls = live-stock type, including dairy cattle, beef cattle, swine, hen, and broiler.

pr = prefecture.

y = year.

LWFW = mass of live-stock waste produced in a year, in fresh weight, Mg y^{-1}

LSN = the number of head of live-stock

LWE = rate of emission of live-stock waste (excrement) in fresh weight per a head of live-stock, kg d^{-1} $head^{-1}$

DN = the number of days in a year

lss = live-stock sub-category, based on class of age or utilization

nlss = the number of live-stock sub-category in different live-stock types (dairy cattle (3); beef cattle (3); swine (2); hen (2); broiler (1))

Equation C.2.2 (Live-stock waste to be utilized for composting, in different type of live-stock);

$$\mathrm{LW4LC}_{ls,pr,y} = \mathrm{LWFW}_{ls,pr,y} \cdot \mathrm{LWCOMP}_{ls}$$

$$\mathrm{LW4SL}_{ls,pr,y} = \mathrm{LWFW}_{ls,pr,y} \cdot \mathrm{LWSL}_{ls}$$

where,

LW4LC = mass of live-stock waste to be utilized for composting (to produce LWC)

LW4SL = mass of live-stock waste to be utilized for slurry production (to produce LWC)

ls = live-stock type, including dairy cattle, beef cattle, swine, hen, and broiler.

pr = prefecture.

y = year.

LWFW = mass of live-stock waste produced in a year, in fresh weight, Mg y^{-1}

LWCOMP = proportion of live-stock waste to be utilized for composting against other usages.

LWSL = proportion of live-stock waste to be utilized for slurry production against other usages.

Equation C.2.3 (Live-stock waste to be utilized for composting, sum of all types of live-stock);

$$\mathrm{LWC}_{pr,y} = \sum_{ls=1}^{nls} \left(\mathrm{LW4LC}_{ls,pr,y} \cdot \mathrm{LWD2F}_{ls} \cdot \mathrm{LWDC}_{ls} \cdot \mathrm{LWCC}_{ls} \right)$$

$$\mathrm{SLC}_{pr,y} = \sum_{ls=1}^{nls} \left(\mathrm{LW4SL}_{ls,pr,y} \cdot \mathrm{LWD2F}_{ls} \cdot \mathrm{LWCC}_{ls} \right)$$

where,

LWC = mass of organic carbon in live-stock waste compost derived from live-stock waste produced in a year in dry weight, Mg C y^{-1}.

SLC = mass of organic carbon in slurry derived from live-stock waste produced in a year in dry weight, Mg C y^{-1}.

pr = prefecture.

y = year.

ls = live-stock type, including dairy cattle, beef cattle, swine, hen, and broiler.

nls = number of live-stock types.

LW4LC = mass of live-stock waste to be utilized for composting (to produce LWC)

LW4SL = mass of live-stock waste to be utilized for slurry production (to produce LWC)

LWD2F = proportion of dry weight against fresh weight of live-stock waste (excrement)

LWDC = residual ratio of live-stock waste after decomposition during composting.

LWCC = concentration of organic carbon in live-stock waste in dry weigh basis, g g^{-1}.

Equation C.2.4 (secondary materials to be utilized for live-stock waste compost production);

$$\mathrm{SMC}_{pr,y} = \sum_{sm=1}^{nsm} \left(\mathrm{LWCOMP}_{pr,y} \cdot \mathrm{SM2LW}_{sm} \cdot \mathrm{SMD2F}_{sm} \cdot \mathrm{SMDC}_{sm} \cdot \mathrm{SMCC}_{sm} \right)$$

where,

SMC = mass of organic carbon in live-stock waste compost derived from secondary materials produced in a year, Mg C y^{-1}

pr = prefecture.

y = year.

sm = secondary material type, including straw, husks, saw-dust, and bark.

nsm = number of secondary materials to be used for composting live-stock waste.

LWCOMP = proportion of live-stock waste to be utilized for composting against other usages.

SM2LW = proportion of applied secondary materials against live-stock waste during composting, based on survey data.

SMD2F = proportion of dry weight against fresh weight of secondary materials for live-stock waste composting.

SMDC = residual ratio of secondary materials used for live-stock waste composting after decomposition during composting.

SMCC = concentration of organic carbon in secondary materials, g g^{-1}.

Equation C.2.5 (bedding materials for live-stock farming used for live-stock waste composting);

$$\mathrm{BDC}_{pr,y} = \sum_{bd=1}^{nbd} \left\{ \left(\sum_{ls=1}^{nls} \mathrm{LSN}_{ls} \cdot \mathrm{BD2LS}_{bd,ls} \right) \cdot \mathrm{BDD2F}_{bd} \cdot \mathrm{BDDC}_{bd} \cdot \mathrm{BDCC}_{bd} \right\}$$

where,

BDC = mass of organic carbon in live-stock waste compost derived from bedding materials for live-stock, Mg yr^{-1}.

bd = bedding materials for live-stocks, including rice-straw, saw-dust, wheat straw, dry grass, hey, and others.

nbd = number of bedding materials for live-stocks.

ls = type of live-stock, including dairy cattle, beef cattle, swine, hen, and broiler.

nls = number of types of live-stock

LSN = the number of head of live-stock.

BD2LS = mass of bedding materials to be applied per a head of live-stock, based on survey data, Mg $head^{-1}$ yr^{-1}.

BDD2F = proportion of dry weight against fresh weight of bedding materials.

BDDC = residual ratio of bedding materials after decomposition during composting.

BDCC = concentration of organic carbon in bedding materials, g g^{-1}.

Equation C.2.6 (food waste to be utilized for composting);

$$\mathrm{FWC}_{pr,y} = \sum_{fi=1}^{nfi} \left(\mathrm{FWCOMP}_{fi,jp.y} \cdot \frac{\mathrm{PN}_{pr,y}}{\mathrm{PN}_{jp,y}} \right) \cdot \mathrm{FWD2F} \cdot \mathrm{FWDC} \cdot \mathrm{FWCC}$$

where,

FWC = mass of organic carbon in compost derived from food waste in a year, Mg yr^{-1}.

pr = prefecture.

y = year.

fi = food industry, including manufacturing, wholesale business, retailing, and foodservice.

nfi = number of food industry

jp = Japan.

FWCOMP = mass of food waste to be utilised for composting in fresh weight, Mg yr^{-1}.

PN = human population in a geographic administrative entity (prefecture or country).

FWD2F = proportion of dry weight of food waste against fresh weight.

FWDC = residual ratio of food waste after decomposition during composting.

FWCC = concentration of organic carbon in food waste, g g^{-1}.

Equation C.2.7 (mass of organic carbon in live-stock waste compost produced in a year);

$$\mathrm{LCC}_{pr,y} = \mathrm{LWC}_{pr,y} + \mathrm{SMC}_{pr,y} + \mathrm{BDC}_{pr,y} + \mathrm{FWC}_{pr,y}$$

where,

LCC = mass of organic carbon in live-stock waste compost produced in a year, Mg yr^{-1}.

pr = prefecture.

y = year.

LWC = mass of organic carbon in live-stock waste compost derived from live-stock waste produced in a year in dry weight, Mg C yr^{-1}.

SMC = mass of organic carbon in live-stock waste compost derived from secondary materials produced in a year, Mg C yr^{-1}.

BDC = mass of organic carbon in live-stock waste compost derived from bedding materials for live-stock produced in a year, Mg C yr^{-1}.,

FWC = mass of organic carbon in live-stock waste compost derived from food waste produced in a year, Mg C yr^{-1}.

Equation C.2.8 (mass of live-stock waste compost applied to soils in different land-use in a year, except managed grasslands);

$$\mathrm{LCC}_{lu,pr,y} = \sum_{cg=1}^{ncg_{lu}} \left(\mathrm{LCI}_{cg,pr,y} \cdot \mathrm{CA}_{cg,pr,y} \cdot \mathrm{FRT}_{cg,lu} \cdot \mathrm{LCD2F} \cdot \mathrm{LCCC} \right)$$

where,

LCC = mass of organic carbon in live-stock waste compost applied to soils in all land-use types in a year, Mg C yr^{-1}.

lu = land-use types, including paddy fields, upland fields, and orchards.

pr = prefecture.

y = year.

cg = cropping group.

ncg = number of cropping group.

LCI = rate of annual live-stock waste compost application to soil, based on questionnaire to farmer, in fresh weight, Mg C ha^{-1} yr^{-1}.

CA = cropping area, ha

FRT = fraction of cumulative cropping area in a year to field area (times of rotation in a year)

LCD2F = proportion of dry weight of live-stock waste compost against fresh weight.

LCCC = concentration of organic carbon in live-stock waste compost, g g^{-1}.

Equation C.2.9 (mass of organic carbon in live-stock waste compost applied to soils in managed grasslands);

$$\mathrm{LCC}_{MG,pr,y} = \mathrm{LCC}_{pr,y} - \sum_{lu=1}^{nlu} \mathrm{LCC}_{lu,pr,y}$$

where,

LCC_{MG} = mass of organic carbon in live-stock waste compost applied to soils in managed grasslands, Mg C yr^{-1}.

pr = prefecture.

y = year.

lu = land-use types, including paddy fields, upland fields, and orchards.

nlu = number of land-use types, including paddy fields, upland fields, and orchards.

Equation C.2.10 (input of live-stock waste compost to soils);

$$\mathrm{LCCI}_{lu,pr,y} = \mathrm{LCC}_{lu,pr,y} / \mathrm{A}_{lu,pr,y}$$

where,

LCCI = rate of application of organic carbon in live-stock waste compost to soils per unit area of fields, Mg C ha^{-1} yr^{-1}.

lu = land-use types, including paddy fields, upland fields, orchards, and managed grasslands.

pr = prefecture.

y = year.

LCC = mass of organic carbon in live-stock waste compost applied to soils, Mg C yr^{-1}.

A = area of fields, ha.